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ABSTRACT

This brief addresses the status of science and mathematics teaching in the United States. The standards of both the National Council of Teachers of Mathematics (NCTM) and the National Research Council (NRC) for science and mathematics education are cited as well as a summary of the findings of the 1993 National Survey of Science and Mathematics Education. The brief focuses on the finding that teachers report instructional objectives consistent with reform goals but class activities are not well aligned with the recommendations of NCTM and NRC. Topics discussed include time spent on science and mathematics instruction, the objectives of science and mathematics education, classroom activities, quality education for all, teachers' views on science and mathematics, and the context for science and mathematics teaching. (DDR)

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NISE BRIEF

REPORTING ON ISSUES AND RESEARCH IN SCIENCE, MATHEMATICS, ENGINEERING, AND TECHNOLOGY EDUCATION

The Status of Science and Mathematics Teaching in the United States

Comparing Teacher Views and Classroom Practice to National Standards

by Iris R. Weiss

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Teachers reported instructional objectives that were consistent with reform goals, but class activities that were not very well aligned with the recommendations of the NCTM and NRC.

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Current efforts to reform science and mathematics education have been given direction by the development of the National Council of Teachers of Mathematics (NCTM) standards (NCTM, 1989, 1991) and the *National Science Education Standards* (National Research Council, 1996). Both of these sets of standards emphasize that science and mathematics education should:

- Emphasize high expectations for all students.
- Focus on in-depth learning of a limited number of powerful concepts, emphasizing understanding, reasoning, and problem-solving rather than memorization of facts, terminology, and algorithms.
- Integrate scientific and mathematical inquiry with knowledge of science and mathematics concepts and principles.
- Engage students in meaningful activities that enable them to construct and apply their knowledge of key science and mathematics concepts.
- Reflect sound principles from research on how students learn; use cooperative learning and techniques for asking questions that promote interaction and deeper understanding.
- Feature appropriate, ongoing use of calculators, computers, and other technologies.
- Empower students by enabling them to do

science and mathematics, and increase their confidence in their ability to do so.

- Develop in students the scientific and mathematical literacy necessary to make informed decisions and to function as full participants in society.
- Assess learning as an integral part of instruction.
- Ensure that teachers have a deep understanding of their subject matter.
- Provide ongoing support for classroom teachers, including continuing opportunities for teachers to work together to plan curriculum and instruction.

A survey conducted in 1993, with the support of the National Science Foundation, provides considerable information about the status of science and mathematics education as they relate to the NCTM and NRC standards. Coordinated by Horizon Research, Inc., the 1993 National Survey of Science and Mathematics Education involved a national probability sample of 1,250 schools and approxi-

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2

While national standards call for reducing the traditional overreliance on factual learning in science and computation in mathematics, many teachers reported emphasizing these objectives in their science and mathematics classes.

mately 6,000 teachers in grades 1-12 throughout the United States (Weiss, Matti, & Smith, 1994). Teachers were asked to provide information about their course backgrounds, participation in inservice education and other professional activities, pedagogical beliefs, and science and mathematics instruction. Department heads or lead teachers also completed questionnaires about their schools' science and mathematics programs.¹

The 1993 National Survey of Science and Mathematics Education asked teachers in grades 1-12 about a randomly selected science or mathematics class.² Generally, teachers reported instructional objectives that were consistent with reform goals, but class activities that were not very well aligned with the recommendations of the NCTM and NRC.

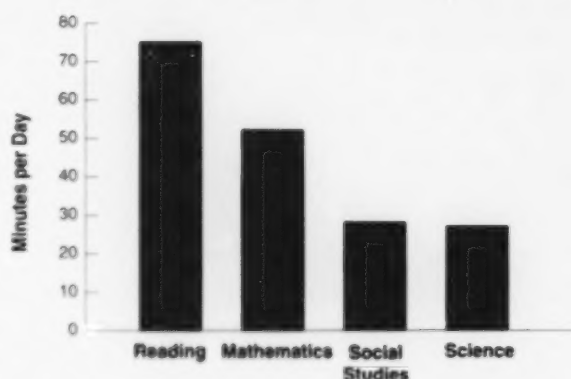
Time Spent on Science and Mathematics Instruction

Based on data provided by the teachers, an average of about half an hour per day was spent on science and mathematics instruction, compared to almost an hour per day on reading/language arts and roughly 70 minutes on mathematics instruction.³ (See Figure 1.) These figures represent small increases during the past 15 years, while the amount of time spent on reading/language arts instruction increased slightly.

In higher grades, most science and mathematics teachers reported for roughly 50 minutes per day, the same amount of time as for other subjects. However, since students are usually required to take 4 years of high school English/language arts, compared to 2 or 3 years of high school mathematics, and typically 2 years of high school science, the pattern is similar to that in the elementary grades: More instructional time is devoted to language arts than to science or mathematics.

Figure 1

Average Number of Minutes per Day Spent Teaching Each Subject in Self-Contained Classes, Grades 1-6



Objectives of Science and Mathematics Education

Teachers were given a list of possible objectives for their classes and asked to indicate how heavily each was emphasized in a particular randomly selected class. Based on the teacher reports:

- The most heavily emphasized objectives in elementary, middle, and high school science classes were learning basic science concepts (heavily emphasized in 83 percent of science classes overall), increasing the awareness of the importance of science in daily life (77 percent), and developing problem solving/inquiry skills (74 percent).

¹ See the National Science Foundation's *Indicators of Science and Mathematics Education* (Suter, 1996) for a summary report on recent changes in science and mathematics education. Chapter 3 of the report summarizes the survey results which are highlighted in this brief.

² The study design included obtaining in-depth information from each teacher about curriculum and instruction in a single randomly selected class. Most elementary teachers taught in self-contained classrooms, meaning they were responsible for teaching all academic subjects to a single group of students. Each of these teachers was randomly assigned to one of two groups—science or mathematics—and received a questionnaire specific to that subject.

³ These numbers represent an average across all self-contained classes in grades 1-6. In fact, teachers in grades 1-3 reported spending substantially more time on reading, somewhat less time on science and social studies, and slightly less time on mathematics than did their counterparts in grades 4-6.



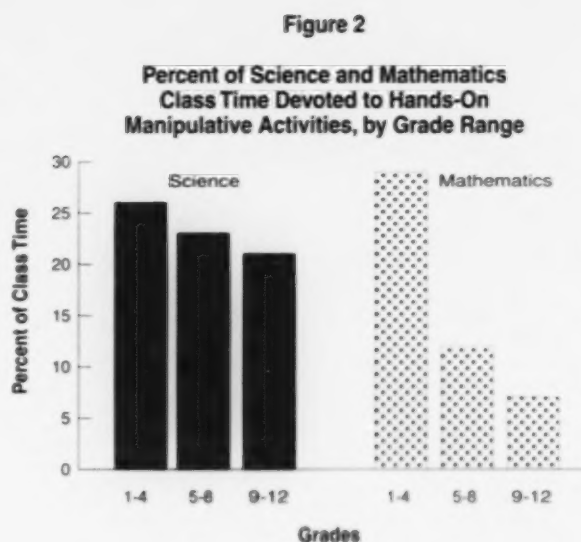
- In mathematics classes, elementary, middle, and high school teachers reported that the most heavily emphasized objectives were learning mathematical concepts (heavily emphasized in 92 percent of classes), learning how to solve problems (91 percent), and learning how to reason mathematically (87 percent).
- In the lower grades, increasing interest in science and mathematics, and increasing awareness of their importance in daily life, were more likely to be emphasized. For example, about 75 percent of the elementary and middle grade classes emphasized increasing interest in science and mathematics, compared to roughly 60 percent of high school classes.

A sizeable proportion of teachers reported instructional emphases that ran counter to the current reform recommendations. For example, approximately 40 percent of mathematics classes and approximately 20 percent of science classes gave heavy emphasis to preparing students for standardized tests, which have been shown to focus on lower level knowledge and skills (Madaus, West, Harmon, Lomax, & Viator, 1992).

Similarly, while national standards call for reducing the traditional overreliance on factual learning in science, and on computation in mathematics, many teachers reported emphasizing these objectives in their science and mathematics classes. One out of every two elementary science classes, and nearly two out of three in the middle/high school grades, gave heavy emphasis to learning "important terms and facts in science." And 54 percent of high school mathematics classes emphasized having students learn mathematical algorithms.

Class Activities

Survey data also show that elementary, middle, and high school science classes were quite similar in their instructional arrangements. In all science classes, the largest proportion of class time was devoted to lecture/discussion (38 percent of class time), followed by hands-on/laboratory work (23 percent), individual seatwork (19 percent), and non-laboratory small group work (10 percent), with the remaining



10 percent of time spent on daily routines, interruptions, and other non-instructional activities.

Mathematics classes appeared to vary considerably more by grade range. For example, the typical high school mathematics class spent 48 percent of class time on whole group lecture/discussion, only 14 percent on small group discussions, and only 7 percent working with manipulatives; the typical elementary mathematics class spent roughly 25 to 30 percent of class time on each of these activities. While the national standards advocate engaging students in the construction of new understanding through hands-on/manipulative activities, such instruction constitutes roughly one-fourth of the time in early grades, and drops steadily as students move to upper grades. (See Figure 2.)

"Traditional" lecture/textbook methodologies continued to dominate science and mathematics instruction. For example, 94 percent of high school science and mathematics classes listened and took notes during presentations by the teacher at least once a week, and 60 percent did so on a daily basis; 98 percent of high school mathematics classes did mathematics problems from their textbooks at least once a week, and 86 percent did so on a daily basis.

In contrast, students in only 4 out of 10 high school mathematics classes were engaged in making conjectures and exploring possible methods to solve a mathematics problem as often as once a week, and

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students in only 3 out of 10 classes were asked at least weekly to write out the reasoning used to solve a problem. Fifty-eight percent of high school mathematics classes never worked on projects of a week's duration or longer, and 56 percent never used computers. Similarly, 62 percent of high school science classes never went on field trips, 54 percent never used computers, and 43 percent never worked on science projects of at least a week's duration.

There were, however, some encouraging signs. The majority of elementary, middle, and high school science and mathematics classes worked in small groups at least once a week, and roughly one in four classes did so every day. Moreover, the use of hands-on activities had increased since the mid-1980s. The change was most dramatic in mathematics in the elementary grades, where the percentage of lessons using manipulatives rose from about 45 percent in 1986 to 65 percent in 1993.

Quality Education for All

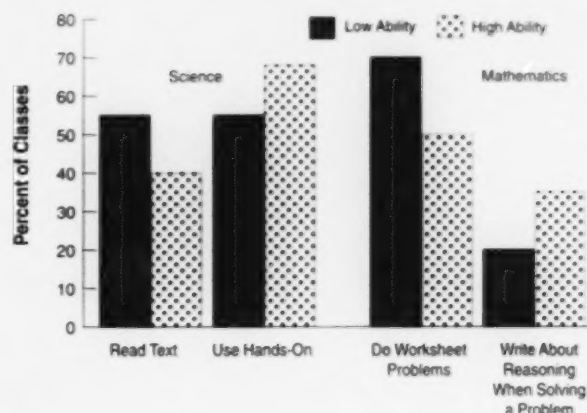
The 1993 survey found evidence that students are not given equal opportunities to achieve high expectations.⁴ Among the findings:

- Roughly 3 in 10 teachers in grades 1-4, and more than 7 out of 10 teachers at the high school level, believed that students learn science and mathematics best when grouped with students of similar abilities.
- Overall, 11 percent of middle/junior high schools assigned students to science courses by ability level; 46 percent did so in mathematics courses.
- Ability grouping was greater at the high school level, with 34 percent of schools assigning incoming students to science courses by ability level and 57 percent doing so in mathematics.

Teachers clearly had different objectives for instruction depending on the composition of a class, the survey data show.⁵ While both "high" and "low" ability high school science and mathematics classes emphasized the

Figure 3

Percent of Low and High Ability High School Classes Participating in Selected Activities at Least Once a Week



"basics," low ability classes were more likely to emphasize awareness of the importance of science and mathematics in daily life, while high ability classes were more likely to focus on developing reasoning and inquiry skills. Thus, students perceived as low ability were often told that science is important, but in many cases were not given the opportunity to experience the power of actually doing science.

The instructional activities engaged in by these classes followed a similar pattern. (See Figure 3.) Low ability high school science classes were more likely than high ability classes to spend time each week reading from the textbook, and were less likely to participate in hands-on activities. Similarly, low ability high school mathematics classes were more likely to spend time each week doing worksheet problems, and were less likely to be asked to write about their reasoning when solving a mathematics problem.

⁴ It is important to note that while some observers believe that implementing "high expectations for all students" requires the elimination of tracking and other grouping practices, the sets of standards discussed here do not take this position. For example, the *National Science Education Standards* note that "there are science activities for which grouping is appropriate and activities for which grouping is not appropriate. Decisions about grouping are made by considering the purpose and demands of the activity and the needs, abilities, and interests of students. A standards-based science program ensures that all students participate in challenging activities adapted to diverse needs" (NRC, 1996, p. 222).

⁵ Teachers were asked whether the students in the randomly selected class were heterogeneous in ability and, if the class was fairly homogeneous, whether the students were low, average, or high in ability.

There is also considerable evidence that classes with high percentages of minority students do not have access to the same resources as other classes. For example, while secondary science classes with various proportions of minority students were equally likely to have teachers with majors in science or science education, mathematics classes with higher proportions of minorities were less likely to have teachers with majors in the field. (See Figure 4.)

Moreover, high school teachers in classes with higher proportions of minority students were more

While there are no data available to compare schools in 1993 to those in earlier years, classroom-level data provided by teachers did show a trend toward heterogeneous grouping in science and mathematics classes.

likely than others to emphasize preparing students for standardized tests—which tend to focus primarily on low level skills—and less likely than others to aim toward preparing students for further study in these fields. (See Figure 5.) This suggests unequal opportunities for students to learn challenging science and mathematics content.

While there are no data available to compare schools in 1993 to those in earlier years, classroom-level data provided by teachers did show a trend toward heterogeneous grouping in science and mathematics classes. In 1993, 36 percent of grade 10-12 science and mathematics classes were heterogeneously grouped, up from 22 percent in 1986 (Weiss, 1987; Weiss, Matti, & Smith, 1994).

Teachers' Views on Science and Mathematics Education

More than 90 percent of science and mathematics teachers at the elementary and middle school levels, and 86 percent at the high school level, indicated that students learn best when they study these subjects in the context of a personal or social application. Similarly, most supported hands-on instruction, indicating that activity-based experi-

Figure 4

Percent of Grade 7-12 Science and Mathematics Classes Taught by Teachers with Undergraduate or Graduate Major in the Field, by Percent Minority Students in Class

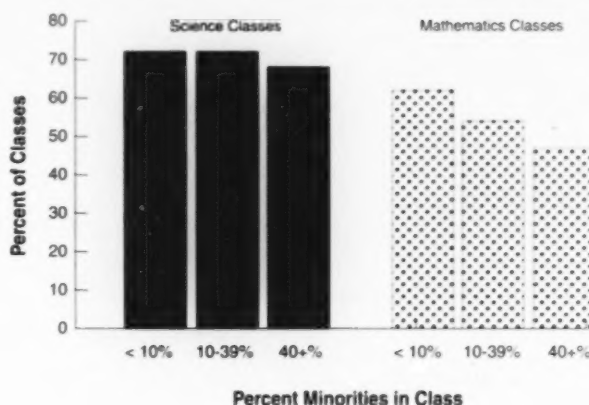
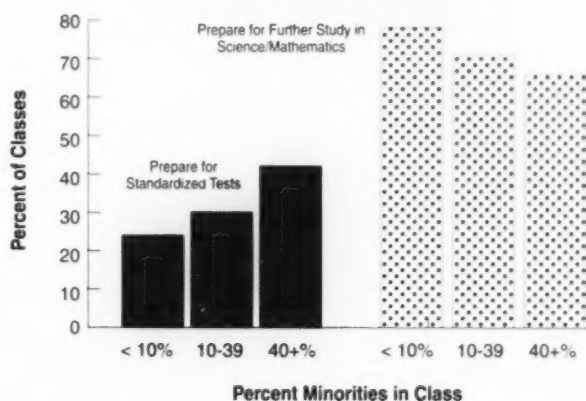


Figure 5

Percent of High School Science and Mathematics Classes Emphasizing Particular Objectives, by Minority Enrollment in Class



ences "are worth the time and expense for what students learn."

There was, however, less support among teachers for some of the other tenets of current reform ideas. For example, while the NCTM *Curriculum and Evaluation Standards* argue for the earlier introduction of algebraic concepts, the majority of elementary, middle, and high school mathematics teachers indicated their belief that "students must master arithmetic computation before going on to



The 1993 survey shows clearly that teachers who believe in reform often do not feel well-prepared to teach the various content areas to their students, or to use the various instructional strategies recommended by the NCTM and NRC standards.

algebra." Similarly, almost a third of the teachers in grades 1-4, and more than half of all high school science teachers, said it is "important for students to learn basic scientific terms and formulas before learning underlying concepts and principles."

Science and mathematics teachers also were provided with a list of instructional "strategies" and asked how important each is for effective science and mathematics instruction. Again, it is clear that science and mathematics teachers supported some of the current reform notions, but were less convinced about others. And again, pedagogical beliefs varied considerably by grade taught. Among the results:

- Almost all teachers supported including the daily-life applications of science and mathematics in their instruction.
- Support for hands-on activities also was very high, although middle and high school mathematics teachers were less likely than elementary teachers to believe that the use of manipulatives is important.
- About 9 out of 10 elementary teachers, and about 8 out of 10 high school science and mathematics teachers, indicated that cooperative learning is important for effective instruction.
- More than 80 percent of science and mathematics teachers, with little difference by grade range, believed that computers are important for effective instruction.⁶

- There was less support for the reform ideas on depth versus breadth. Roughly 70 percent of elementary and middle grade teachers, and fewer than 60 percent of high school teachers, indicated that science and mathematics instruction should focus on deeper coverage of fewer concepts.

While elementary teachers were generally supportive of the various reform ideas, there was some resistance to the extensive use of calculators. Only 71 percent of grade 1-4 teachers, compared to 89 percent of high school mathematics teachers, said that calculators should be used in mathematics instruction at their grade levels. And only 24 percent of grade 1-4 teachers indicated that students should be able to use calculators "most of the time" in mathematics classes, compared to 73 percent of high school mathematics teachers.

The Context for Science and Mathematics Teaching

The 1993 survey shows clearly that teachers who believe in reform often do not feel well-prepared to teach the various content areas, or to use the various instructional strategies recommended by the NCTM and NRC standards. Nor do they feel they get the support they need to plan and deliver quality instruction. At the elementary level, where most teachers are assigned to teach science, mathematics, and other academic subjects to one group of students, 76 percent of teachers reported feeling very well-qualified to teach reading. By comparison, roughly 60 percent felt very well-qualified to teach mathematics and social studies; only 28 percent felt very well-qualified to teach life science; and fewer than 10 percent felt very well-qualified in the physical sciences.

Science and mathematics teachers at all grade levels also were asked how well-prepared they felt for a number of tasks. Several areas stood out as ones in which large numbers of teachers felt inadequately prepared.

⁶ The question about importance for effective teaching did not specify how computers would be used, so it is not possible to tell whether teachers were rating the importance of using computers for exploring problems or simply for drill and practice.

For example:

- Half or more of the science and mathematics teachers in each grade range did not feel well-prepared to use computers as an integral part of instruction.
- More than a third of elementary teachers, and more than half of high school science and mathematics teachers, felt unprepared to involve parents in the education of their children.
- Roughly 40 percent of all science and mathematics teachers felt they lacked preparation in the use of performance-based assessment.
- About 1 in 4 science and mathematics teachers felt less than well-prepared to use textbooks as a resource rather than as the primary instructional tool.
- About 1 in 5 mathematics teachers and 1 in 3 science teachers did not feel well-prepared to take into account students' prior conceptions about natural phenomena when planning curriculum and instruction.

Interestingly, elementary teachers tended to be more comfortable with a number of the reform strategies than their colleagues in the higher grades, including the use of cooperative learning techniques, heterogeneous grouping, and integrating science and mathematics with other subject areas. On the other hand, elementary teachers expressed more concern than middle and high school teachers about using calculators as an integral part of mathematics instruction, and about presenting the applications of science concepts.

Conclusions

Overall, science and mathematics teachers were quite supportive of the kind of science and mathematics instruction described in the NCTM and NRC standards. They agreed with the standards about what is important for effective science and mathematics instruction, and they embraced the reform goals. However, the instructional strategies teachers used to achieve these goals often were not the ones they themselves said were most effective, leaving classroom instruction far from the vision described in the NCTM and NRC standards.

The survey data indicated quite different patterns of strengths and weaknesses at different levels of schooling. While elementary teachers tended to be confident about using reform-oriented strategies such as cooperative learn-

While there has been some progress made in increasing the number of students who take rigorous science and mathematics courses, classes with large numbers of minority students were less likely to have access to well-qualified teachers and other resources.

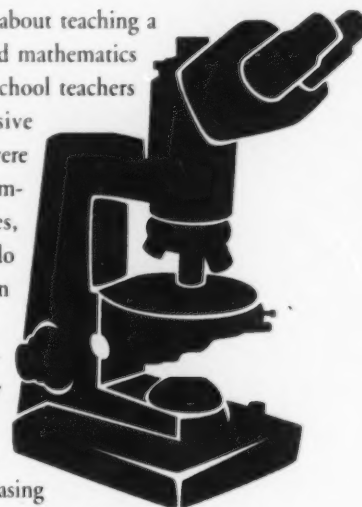
ing, many did not feel confident about teaching a number of elementary science and mathematics content areas. In contrast, high school teachers were more likely to have extensive preparation in their subjects, but were less supportive of the use of reform-oriented instructional techniques, less confident of their ability to do so, and less likely to use them in their classes.

There was also considerable evidence that the goal of quality education for all students has not yet been achieved. While there has been some progress made in increasing the number of students who take rigorous science and mathematics courses, classes with large numbers of minority students were less likely to have access to well-qualified teachers and other resources.

Finally, it is essential that reform efforts recognize that while the NCTM and NRC standards call for high expectations and quality instruction for all students, schools are not alike in their capacity to implement these recommendations. Policymakers must take steps to ensure that adequate resources—including well-prepared teachers, appropriate facilities, and high quality instructional materials—are available to all schools. Otherwise, schools without the resources to effectively implement new, higher standards will be left even further behind.

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FOR FURTHER READING

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